

7. The condition of marked swelling of the lymphatic glands is one of, if not indeed the most evident pathognomic feature of the disease. The contagium exists as a primary infection in the lymphatic glands.

8. A very mild attack of rinderpest, such as is produced by injection of blood of greatly decreased virulence, does not convey absolute immunity, this latter being produced in proportion to the severity of the attack through which the animal had passed primarily. An animal seemingly affected may have a relapse of the disease, which may go on to fatal issue or be mild in type, leading to recovery. Animals in the latter case always acquire immunity of a high degree.

“On the Dielectric Constants of certain Organic Bodies at and below the Temperature of Liquid Air.” By JAMES DEWAR, M.A., LL.D., F.R.S., Fullerian Professor of Chemistry in the Royal Institution, and J. A. FLEMING, M.A., D.Sc., F.R.S., Professor of Electrical Engineering in University College, London. Received June 29, 1897.

Continuing the researches on which we are engaged on the Dielectric quality of matter at very low temperatures, we have examined a number of organic bodies and measured their dielectric constants at and above the temperature of liquid air.

The apparatus and arrangements for effecting this measurement are described in a former communication by us on the same subject.*

The frequency of the reversals of the electromotive force used in charging the condenser in the experiments here described was, as before, 120. The condenser used was the gilt cone condenser described in the communication mentioned.

In another paper† we have given the results obtained by us on the measurement of the dielectric constants of glycerine, ethylene dibromide, and nitrobenzol at very low temperatures, and shown that in the case of glycerine the very high value of the dielectric constant possessed by this body, above -100° C., is reduced, on cooling to -185° C., to a value not far from 3.0. We have also shown that a similar great reduction in the value of the dielectric constant takes place in the case of ethyl alcohol when frozen at -185° C.‡

* See Fleming and Dewar, “On the Dielectric Constants of Certain Frozen Electrolytes at and above the Temperature of Liquid Air,” ‘Roy. Soc. Proc.,’ vol. 61, p. 299.

† See Fleming and Dewar, “On the Dielectric Constants of Ice, Glycerine, Ethylene Dibromide, and Nitrobenzol at and above the Temperature of Liquid Air,” ‘Roy. Soc. Proc.,’ vol. 61, p. 316.

‡ See Dewar and Fleming, “Note on the Dielectric Constants of Ice and Alcohol at very Low Temperatures,” ‘Roy. Soc. Proc.,’ vol. 61, p. 2.

We have now examined, in addition, the following organic bodies, viz., *formic acid*, *methyl alcohol*, *amyl alcohol*, *acetone*, *chinoline*, *tetraethylammonium hydrate*, and *carbolic acid*, and we find that these bodies have, in the liquid or solid condition and at temperatures above -100°C ., high, or very high, dielectric values, but all have their dielectric constants reduced to a value not far from 2.5 when they are cooled to the temperature of liquid air.

In addition, we have measured the dielectric constants of *castor oil* and *olive oil*, and find that they are reduced in value when these oils are cooled to -185°C . We have also measured the dielectric constants of *bisulphide of carbon*, *ether*, *ethyl nitrate*, *solution of sulphur in bisulphide of carbon*, and *absolute alcohol* with 10 per cent. of metallic sodium in it. We find in all these cases that there is a reduction in the value of the dielectric power, large or small, these bodies possess at normal temperatures. These experiments further confirm the view that the presence of the radicles *hydroxyl* (HO), *carbonyl* (CO), and the organic acid radicle (COOH) always produce relatively high dielectric values in the bodies containing them when these bodies are in the liquid condition or at temperatures not very far below their freezing points. When these bodies are, however, frozen and cooled to the temperature of liquid air, all of them suffer a reduction in dielectric power, and their dielectric constants are reduced to values not far from 2.5, or between 2.5 and 2.6, at the temperature of -185°C . or a little below. The action of the low temperature is thus to annul the effect of the radicle.

We have not found, so far, any exception to the rule that pure organic bodies have a dielectric constant of from two to three times that of vacuous space when they are cooled to the temperature of boiling liquid air, no matter what value their constant may have when in the liquid condition.

The following tables give the numerical results, and the observations are delineated graphically in the chart in fig. 1.

All the tables are headed by a statement giving the galvanometer scale deflection in centimetres when the condenser has air as dielectric. This is to be understood as the constant, for the time being, representing the capacity of the condenser when its dielectric is gaseous air at normal pressure and temperature. The numbers in the columns headed "Dielectric constant," under each substance are obtained by dividing the number in the second column of the tables, headed "Mean galvanometer deflection," by the above air capacity constant, after having applied a correction to the galvanometer reading for the charging voltage and for the capacity of the leads. The numbers headed "Mean galvanometer deflection," when corrected for voltage and the capacity of the leads and vibrator, represent, to the same scale as the corrected air capacity constant, the capacity

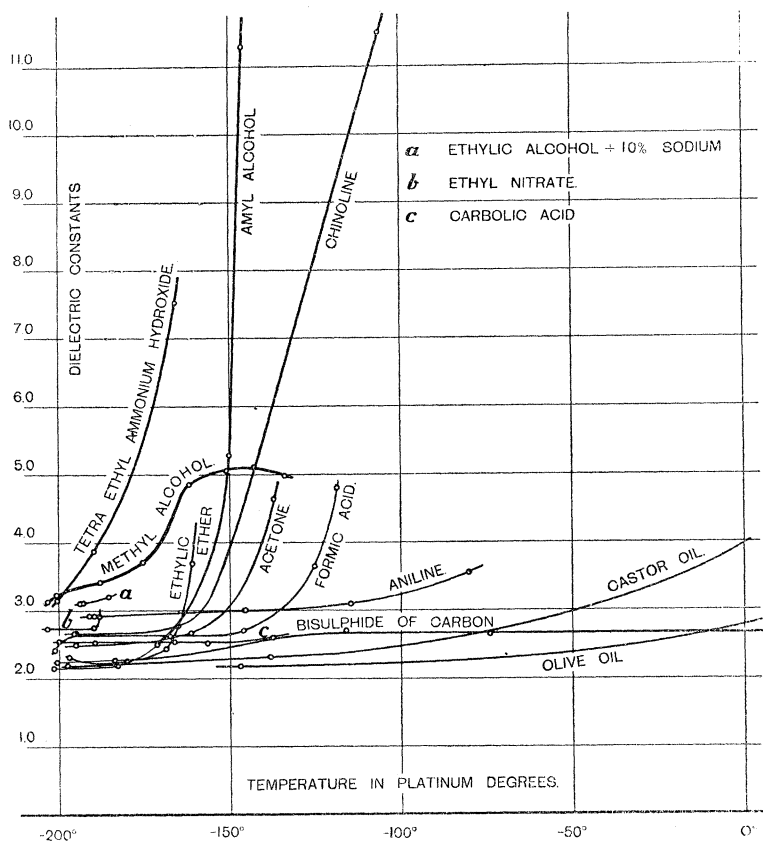


FIG. 1.—Curves showing the Variation in Dielectric Constant with Temperature of Various Organic Bodies.

of the condenser when the particular substance mentioned was being used as dielectric. The temperatures are given in platinum degrees, as explained in our other papers to which reference is made. The last column in the tables gives the electromotive force, in volts, used to charge the condenser. The frequency of reversals was in all cases 120 per second.

The observations were stopped in each case at that temperature at which any sensible true conductivity made its appearance in the dielectric, and this, as we have already shown, takes place in the case of many bodies quite suddenly, and at temperatures far below their melting point. Thus it is impossible to carry up the dielectric constant measurement, by the method we employed, of formic acid or methyl alcohol much above about -120° , because at that point

sensible conductivity begins. There is no difficulty, however, in carrying out the measurement in the case of carbon bisulphide, castor oil, or olive oil, over the whole range from -200° up to $+15^{\circ}$. At the liquid air temperature all the organic bodies in the following tables are, however, practically perfect insulators.

The following tables give the figures of observation :—

I. *Methyl Alcohol* (CH_4O).

Corrected galvanometer deflection when the condenser had air as dielectric = 3.96 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| —203.4 | 13.2 | 3.13 | Condenser charged to 102 volts. |
| —200.8 | 13.5 | 3.23 | |
| —188.0 | 14.2 | 3.41 | |
| —175.4 | 15.4 | 3.71 | Condenser charged to 18.3 volts. |
| —161.9 | 19.75 | 4.85 | |
| —151.0 | 3.71 | 5.05 | |
| —143.0 | 3.75 | 5.10 | |
| —134.0 | 3.78 | 4.98 | |

II. *Amyl Alcohol* ($\text{C}_5\text{H}_{12}\text{O}$).

Corrected galvanometer deflection when the condenser had air as dielectric = 4.24 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| —204.0 | 10.4 | 2.40 | Condenser charged to 98.2 volts. |
| —201.8 | 1.89 | 2.14 | Condenser charged to 18.6 volts. |
| —183.0 | 1.93 | 2.19 | |
| —171.5 | 2.05 | 2.50 | |
| —150.2 | 4.30 | 5.28 | Condenser charged to 1.43 volts. |
| —146.2 | 9.00 | 11.3 | |
| —141.4 | 19.50 | 24.7 | |
| —138.8 | 2.10 | 34.4 | |
| —133.3 | 2.61 | 43.0 | |
| —127.7 | 2.55 | 42.0 | |
| —123.8 | 2.50 | 41.0 | |

III. *Formic Acid* (CH_2O_2).

Corrected galvanometer deflection when the condenser had air as dielectric = 3.97 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| —201.3 | 9.88 | 2.41 | Condenser charged to 99.0 volts. |
| —195.8 | 1.95 | 2.66 | Condenser charged to 17.8 volts. |
| —167.5 | 1.93 | 2.62 | |
| —146.1 | 1.98 | 2.70 | |
| —125.2 | 2.65 | 3.65 | |
| —118.8 | 3.45 | 4.80 | |

IV. *Absolute Ethylic Alcohol* ($\text{C}_2\text{H}_5\text{O}$), having 10 per cent. of sodium dissolved in it.

Corrected galvanometer deflection when the condenser had air as dielectric = 4.04 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| —193.0 | 12.95 | 3.11 | Condenser charged to 99.7 volts. |
| —194.0 | 12.95 | 3.11 | |
| —185.6 | 13.25 | 3.20 | |

V. *Acetone* ($\text{C}_2\text{H}_5\text{CO}$).

Corrected galvanometer deflection when the condenser had air as dielectric = 4.24 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| —198.3 | 11.30 | 2.62 | Condenser charged to 98.8 volts. |
| —195.2 | 2.05 | 2.49 | Condenser charged to 18.7 volts. |
| —161.5 | 2.18 | 2.66 | |
| —137.2 | 3.75 | 4.63 | |

VI. *Aniline* ($\text{C}_6\text{H}_5\text{NH}_2$).

Corrected galvanometer deflection when the condenser had air as dielectric = 4.05 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|---------------------------------|
| -191.2 | 12.2 | 2.92 | Condenser charged to 100 volts. |
| -189.7 | 12.2 | 2.92 | |
| -145.5 | 12.55 | 3.00 | |
| -114.7 | 12.9 | 3.09 | |
| -80.0 | 14.78 | 3.55 | |

VII. *Carbolic Acid* ($\text{C}_6\text{H}_5\text{O}$).

Corrected galvanometer deflection when the condenser had air as dielectric = 4.34 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| -200.0 | 11.25 | 2.54 | Condenser charged to 98.2 volts. |
| -189.5 | 11.18 | 2.53 | |
| -166.2 | 11.25 | 2.33 | |
| -156.5 | 11.15 | 2.52 | |
| -137.3 | 11.50 | 2.60 | |

VIII. *Tetraethylammonium hydroxide* ($\text{N}(\text{C}_2\text{H}_5)_4\text{HO}$).
(10 per cent. solution.)

Corrected galvanometer deflection when the condenser had air as dielectric = 4.24 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| -200.5 | 13.63 | 3.15 | Condenser charged to 98.7 volts. |
| -189.8 | 3.00 | 3.87 | |
| -165.7 | 5.75 | 7.52 | Condenser charged to 17.8 volts. |

IX. *Chinoline* (from Cinchonine).

Corrected galvanometer deflection when the condenser had air as dielectric = 4.05 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| -195.0 | 11.1 | 2.67 | Condenser charged to 99.0 volts. |
| -165.2 | 11.55 | 2.77 | |
| -106.0 | 8.50 | 11.5 | Condenser charged to 18.0 volts. |
| -93.6 | 9.75 | 13.3 | |

X. *Bisulphide of Carbon* (CS₂).

Corrected galvanometer deflection when the condenser had air as dielectric = 4.13 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| -200.7 | 9.43 | 2.24 | Condenser charged to 98.2 volts. |
| -183.8 | 9.60 | 2.27 | |
| -116.2 | 11.35 | 2.70 | |
| -74.2 | 11.10 | 2.64 | |
| +20.0 | 11.11 | 2.64 | |

XI. *Solution of Sulphur in Bisulphide of Carbon.*

Corrected galvanometer deflection when the condenser had air as dielectric = 4.04 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| -152.8 | 11.0 | 2.65 | Condenser charged to 99.2 volts. |
| +20.0 | 11.5 | 2.77 | |

XII. *Ethyllic Ether* (C₄H₁₀O).

Corrected galvanometer deflection when the condenser had air as dielectric = 3.96 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|---------------------------------|
| -197.0 | 9.75 | 2.31 | Condenser charged to 100 volts. |
| -194.0 | 10.95 | 2.61 | |
| -180.2 | 9.52 | 2.25 | |
| -168.8 | 10.25 | 2.43 | |
| -161.2 | 15.35 | 3.69 | |

XIII. *Ethyl Nitrate* ($C_2H_5NO_3$).

Corrected galvanometer deflection when the condenser had air as dielectric = 4.34 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| -203.8 | 12.25 | 2.73 | Condenser charged to 99.8 volts. |
| -190.0 | 12.33 | 2.75 | |
| -188.4 | 13.05 | 2.92 | |

XIV. *Castor Oil*.

Corrected galvanometer deflection when the condenser had air as dielectric = 4.13 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| -197.7 | 9.30 | 2.19 | Condenser charged to 98.2 volts. |
| -138.3 | 9.75 | 2.31 | |
| + 20.0 | 17.5 | 4.23 | |

XV. *Olive Oil*.

Corrected galvanometer deflection when the condenser had air as dielectric = 4.13 cm. for 100 volts.

| Temperature in platinum degrees. | Mean galvanometer deflection in cm. | Dielectric constant. | Observations. |
|----------------------------------|-------------------------------------|----------------------|----------------------------------|
| -147.2 | 9.2 | 2.18 | Condenser charged to 98.2 volts. |
| + 20.0 | 12.0 | 2.86 | |

The observations on castor oil, olive oil, and bisulphide of carbon are of considerable interest.

In the first place they show that the method we are using gives results at normal temperatures which are in agreement with those of other observers. Thus Dr. J. Hopkinson* found the dielectric constant K of carbon bisulphide at 20° C. to be 2.67: we find it to be 2.64. The square of the refractive index of carbon bisulphide for the D ray at 10° C. is 2.673, and accordingly this body is generally said to be one of those which obey Maxwell's law, in that its refractive index is nearly equal to the square root of the dielectric constant. If, however, we calculate the square of the refractive index of bisulphide of carbon for waves of infinite wave-length using at least

* See 'Roy. Soc. Proc.' vol. 43, p. 161, 1887.

two terms of the Cauchy's formula,* we find that for carbon bisulphide the value of $(\mu_{\infty})^2$ is 2.01, and this is somewhat less than the value (2.67) of K at ordinary temperatures. It is, however, much nearer to the value (2.24) which we find for K at the liquid air temperature. Again, Dr. J. Hopkinson's value for the dielectric constant of castor oil at normal temperature is 4.78, and the square of the refractive index of this body for infinite waves is 2.153. Our value for the dielectric constant of castor oil is 4.23 at 20° C. and 2.19 at -185° C.

Hence, in the case of castor oil at the temperature of liquid air there is practically a very fair agreement between the values of K and $(\mu_{\infty})^2$ for a low frequency of electromotive force reversals, whereas at normal temperatures K has nearly twice the value of $(\mu_{\infty})^2$.

The same fact holds good for olive oil. At normal temperatures its dielectric constant K is 3.16, and the square of its infinite refractive index $(\mu_{\infty})^2$ is 2.131. At the temperature of liquid air we find the dielectric constant of olive oil to be 2.18 for low frequency. Hence, in these cases a large part of the difference between K and $(\mu_{\infty})^2$ which exists at normal temperature disappears at very low temperatures, and castor oil and olive oil then make in this respect even a better agreement than carbon bisulphide. One other point is of interest. The temperature variation of dielectric constant for both olive oil and carbon bisulphide appear to be negative at ordinary temperatures,† that is to say, their dielectric constants decrease with rise of temperature. At low temperatures, however, we find their constants to have a positive temperature coefficient; in other words, they increase with temperature. Hence, it follows that, like ice and glycerine, they have at some temperature a *maximum* value for their dielectric constant.

The following table shows the relative values of the dielectric constants (K) of certain of these organic bodies at 15° and at -185° C for low frequency. At the same time the value of $(\mu_{\infty})^2$ calculated by Cauchy's formula is placed against them as far as we have been able to find it determined.

It is clear, therefore, that in all the above cases a very low temperature extinguishes the high dielectric values many organic bodies have in the liquid condition, and it produces the same effect, therefore, as a sufficient increase in the frequency of the electromotive force reversals. Either of these operations tends to bring down the high value of the dielectric constant to a value much more comparable in magnitude with the square of the optical refractive index as calcu-

* We here make the assumption that even for a highly dispersive body like carbon bisulphide, the Cauchy formula is applicable for calculating $(\mu_{\infty})^2$, an assumption perhaps not warranted.

† See Cassie, 'Roy. Soc. Proc.,' vol. 46, 1889.

Dielectric Constants of some Organic Bodies at Normal and at very Low Temperatures for Low Frequencies.

| Substance. | Dielectric constant (K) | | (Infinite Refractive Index) ² = (μ_{∞}) ² . |
|--------------------------|---------------------------|--------------------------------------|------------------------------------------------------------------------------|
| | at 15° C. | at - 185° C. (Dewar and Fleming.) | |
| Methyl alcohol..... | 34.0 (Thwing)... | 3.13 | — |
| Ethyl alcohol..... | 25.8 (Nernst)... | 3.11 | 1.831 |
| Amyl alcohol | 16.0 (Nernst)... | 2.14 | 1.951 |
| Formic acid | 62.0 (Thwing)... | 2.41 | — |
| Acetone | 21.85 (Thwing)... | 2.62 | — |
| Ethyl ether | 4.25 (Nernst)... | 2.31 | 1.805 |
| Castor oil | 4.78 (Hopkinson) | 2.19 | 2.153 |
| Olive oil | 3.16 " | 2.18 | 2.131 |
| Bisulphide of carbon ... | 2.67 " | 2.24 | 2.010 |
| Aniline | 7.51 (Smale) | 2.92 | — |
| Carbolic acid | | 2.54 | — |
| Ethyl nitrate..... | 17.72 (Thwing) .. | 2.73 | — |

lated by Cauchy's formula for infinite wave-lengths, on the assumption that there is no anomalous dispersion.

The determination of the actual values of the refractive indices of these bodies at the liquid air temperature is a work of great difficulty, and one which we have not yet attempted. There is no question that it is important also to determine whether these very low temperatures have any effect in altering the absorptive power of these organic bodies for ultra-red rays, and removing that anomalous dispersion which appears to exist in some of them beyond the limits of the visible spectrum.

We are much indebted to Mr. J. E. Petavel for assistance in the work of taking the above described observations.